Materials and methods for tagging tuna and billfishes, recovering the tags and handling the recapture data

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Tunas and billfishes are important resources of the tropical and temperate waters of the Pacific, Atlantic, and Indian Oceans. Considerable research is carried out on the more important species, and tagging is an important aspect of this research. Because the fish, the larger fishing vessels, and ships which carry frozen tunas to ports where they are to be processed, often travel great distances, it is especially important that there be exchange of information and cooperation among persons involved in tuna and billefish tagging studies. This report was prepared with that in mind, through correspondance between the members of the informal FAO Working Party on Tuna and Billfish Tagging of which Dr. W.H. Bayliff is the convenor.

Useful suggestions for improvements of this report were received from Drs. Robert E. Kearney, Jacek Majkowski, Peter M. Miyake, and Alexander Wild, and Messrs. Terry J. Foreman, Robert D. Gillett, Edwin L. Scott, and James L. Squire, Jr.

Distribution

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ABSTRACT

Conventional tags are applied to tunas and billfishes, using several different methods to handle the fish. The importance of making satisfactory arrangements for collecting the tagged fish which are recaptured, and the pertinent data, is discussed. Some suggestions for handling the data are given. Ultrasonic telemetry has been used extensively on tunas and billfishes during the last few years. Fishing techniques, transmitter attachment, hydrophone systems, and data collection and storage are discussed. Some tagging systems which may be used on tunas and billfishes in the future are described.

CONTENTS

		Page
1.	INTRODUCTION	1
2.	CONVENTIONAL TAGS	1
	2.1 Tagging	1
	2.1.1 Vessels and gear	1
	2.1.2 Methods for handling the fish	2
	2.1.2.1 In-the-water method	2
	2.1.2.2 Winging	2
	2.1.2.3 Deck method	2
	2.1.2.4 Cradle method	3
	2.1.2.5 Chute method	3
	2.1.3 Tags, applicators, and holders	8
	2.1.4 Recording equipment and materials	11
	2.1.5 Daily routine	11
	2.1.6 Rates of tagging and numbers of fish which can be tagged per day	16
	2.1.7 Double tagging	16
	2.1.8 Antibiotics for prevention of infection	17
	2.1.9 Lactic acid and sodium bicarbonate	17
	2.1.10 Tetracycline injection	17
	2.2 Recaptures, recoveries, reports, and returns	18
	2.3 Handling the data	22
	2.3.1 Release data	22
	2.3.2 Recapture data	22
	2.3.3 Checking the data for errors	24
	2.3.4 Additional ICCAT procedures	24
3.	ULTRASONIC TELEMETRY	24
	3.1 General	24
	3.2 Fishing techniques	26
	3.3 Transmitter attachment	26
	3.4 Hydrophone systems	28
	3.5 Data collection and storage	29
4.	FUTURE PROSPECTS	29
5.	LITERATURE CITED	32
	APPENDIX	36

1. INTRODUCTION

Tunas and billfishes are tagged to obtain information about their movements, migrations, stock structure, growth, population size, mortality, schooling behavior, and physiology, and about the effects of various patterns of fishing on the fish and the fisheries. About 500,000 tunas and billfishes have been tagged with conventional external tags of various kinds, and roughly 10 percent of the tags have been returned. In addition, about 50 tunas and billfishes have been tagged with external or internal sonic tags which have been monitored by receivers aboard research vessels.

Tunas and billfishes are currently being tagged by many different organizations in all parts of the world where they occur, and fishermen and fish handlers of many nations have the opportunity of encountering tagged fish. Tagging these large, active fish is not easy, and workers who have had relatively little experience with this type of work can profit from the experiences of those who have. Many of the tags which have been returned have been accompanied by incomplete data, or no data at all, so obviously there is a need for better systems for collection of the required information for the tagged fish which are recaptured. This report is a summary of the methods used to tag tunas and billfishes, secure the return of the tags from those which are recaptured, along with the required information, and store the data in readily-accessible forms. Some recommendations for improvements in these methods are made. In addition, some possible future developments are discussed.

The desirability of uniformity in the various aspects of tagging work will be mentioned from time to time in this report. It is well to point out in the beginning, however, that tuna and billfish research in the Atlantic Ocean is coordinated by the International Commission for the Conservation of Atlantic Tunas (ICCAT), and this organization has recommended procedures for tagging, handling the return data, etc., which have be adopted almost completely by virtually all the organizations which tag tunas and billfishes in the Atlantic Ocean (Miyake and Hayasi, 1978; ICCAT, 1983 : 214-219). Accordingly, any organization contemplating tagging tunas or billfishes in the Atlantic Ocean for the first time should confer first with the secretariat of the ICCAT. Most of the tagging of tunas and billfishes in the Pacific Ocean has been carried out by a few organizations, so it would be well for an organization contemplating tagging in the Pacific Ocean for the first time to attempt to coordinate its work with that of the organization(s) with considerable experience in the part of the Pacific Ocean in which the work is to be carried out.

2. CONVENTIONAL TAGS

2.1 Tagging

2.1.1 Vessels and gear

The fish may be tagged a few seconds to a few minutes after they are caught and in the same sequence that they are caught (baitboat, trolling, or sport-fishing gear), or they may be tagged longer periods of time after they are caught and not in the same sequence that they are caught (purse seines, traps, gill nets, or longlines). Much more success has been realized from experiments in which the fish are tagged a few seconds to a few minutes after they were caught. The return rates for tagged purse seine-caught tunas are lower than those for tagged baitboat-caught tunas, and the return rates decrease as the times of confinement in the net prior to tagging and release increase (Bayliff, 1973). In some cases, at least, large portions of the fish tagged and released from traps are recaptured by the same traps within a few days.

2.1.2 Methods for handling the fish

The fish must be handled gently, but tagged and returned to the water as quickly as possible. They should not be dropped on the deck or allowed to strike the side of the boat or a bulkhead. When picked up they should be held horizontally, and the gills should not be touched with the fingers. A wet towel over the eyes often helps reduce their struggles. There are at least five different methods for handling the fish during tagging, the in-the-water method, "winging," the deck method, the cradle method, and the chute method.

2.1.2.1 In-the-water method

The in-the-water method is employed by sport fishermen for fish which are too large to be brought aboard the vessel. The fish is brought near the side of the boat as quickly as possible, where it is tagged.

> "We found that with the boat moving slowly ahead, and the man holding the leader somewhat forward of the tagger, the fish would usually be brought into a position favorable for tagging... After tagging fish were released by cutting the leader close to the hook" (Mather, 1963).

> "If necessary, ... the billfish [would] be towed forward slowly before release to provide an additional supply of oxygen to assist in reviving the fish" (Squire, 1974).

In general, the in-the-water method is not a good way to tag fish, as some of them are in poor condition, due to having struggled for some time during capture. Also, it is not possible to measure fish handled in this manner with accuracy. No other way has been found to handle very large fish, however, and returns from fish tagged in this manner (including some which were in poor condition) have added considerably to understanding of the biology of billfishes and large tunas.

2.1.2.2 Winging

Winging has been used from time to time with skipjack, Katsuwonus pelamis (Yamashita and Waldron, 1958; Fisheries Agency of Japan and Department of Primary Industry, Papua New Guinea) and albacore, Thunnus alalunga (Laurs, Lenarz and Nishimoto, 1976).

> "In the fishing operation, as commonly practiced by Hawaiian fishermen, skipjack are hooked, swung up, caught under the left arm, and unhooked. The tagger stands one to two feet [1/2 m] behind the fishermen; ordinarily there is one tagger to two fishermen. After the skipjack is caught and while the hook is being removed, the tag-bearing needle is inserted usually from the right side" (Yamashita and Waldron, 1958).

Laurs, Lenarz, and Nishimoto (1976) measured the albacore with a caliper. Skipjack ranging in weight from 2 to 25 pounds (1 to 11 kg) have been tagged by this method. In general, this method is inferior to the cradle method, described below, because so much skill is required and because it is difficult to measure the fish accurately. In addition, it probably results in more damage to the fish than does the cradle method. Sometimes, however, when space is limited, there are only a few fish to be tagged, and the fisherman and tagger are skillful, this method is appropriate.

2.1.2.3 Deck method

The deck method has been used mostly with large tunas. Its employment was first reported by Fink and Bayliff (1970), who used it for large

yellowfin, *Thunnus albacares*, on a baitboat. Improvements for this method are described by I-ATTC/CIAT, 1981:26, who stated that,

> "the entire [stern] deck of the vessel and the sides of the bait tanks adjacent to the deck were heavily padded with energy-absorbing (closed cell) plastic foam covered with Herculite, a smooth plastic material, which made it possible to slide the fish into position with relative ease and without removing excessive amounts of mucous from them. Fishing took place only at the port stern corner of the boat, and fish were tagged at the starboard stern corner and on the port side about 4 meters forward of the stern. The horizontal padding was raised slightly with extra padding at the port stern corner so approximately equal portions of the fish slid toward the two tagging stations. The fish were slid onto flat cradles with noseblocks so that they could be measured accurately. After being tagged, injected [with tetracycline, as described later], and measured the ones at the starboard stern corner were slid overboard through a small door cut in the starboard ... [bulwark] of the boat, and those on the port side were slid up a slight incline over the rail."

> The deck method has also been employed for purse-seine caught fish.

> "The fish are held on 2-inch (5.1-cm) thick 2 1/2- by 4 1/2-foot (76- by 137-cm) pads of foam plastic covered with Naugahyde [a strong, smooth fabric] marked in 1-cm intervals... Tagging ... is accomplished by two teams of three to five men each working in the skiff, one team in the bow and the other in the stern. The extra men come aboard the skiff when the net is nearly all aboard the vessel. Each team consists of two or three fish handlers, mostly fishermen, one tagger, and sometimes one recorder who hands the tags to the tagger as well as recording the tag numbers and the species and lengths of the fish... The latter have been eliminated on most sets of the more recent cruises, the data being recorded with tape recorders... The fish are removed with from the net with large dipnets handled by men in the skiff or by hand by men standing thigh-deep in the water inside the net in aluminum racks. The latter method has been used more than the former on more recent cruises because with it the fish can be obtained from the net more easily... Throughout the period of tagging the net is held open by towing the skiff away from the vessel with a speedboat equipped with a 65-hp outboard motor tied to its port side" (Bayliff, 1973).

Tuna tagging in a purse-seine skiff is shown in Figure 1.

The deck method is satisfactory for baitboat-caught fish which are too large to be lifted into and out of cradles such as those described below. It is the best method which has been found for tagging purse-seine caught tunas, but confinement in the net is harmful to the fish, and the return rates are usually low.

2.1.2.4 Cradle method

More tunas have been tagged by the cradle method than by any other method. There are two basic types of cradles, those which hold only one fish at a time and those which hold more than one fish at a time. These will henceforth be called small and large cradles, respectively.

Small cradles are described by Wilson (1953) and Fink (1965). A small cradle is essentially a V-shaped trough, usually made of aluminum, closed at one or both ends. It is covered with padding, which is usually covered with smooth plastic fabric. The fish is placed in the cradle, the hook is

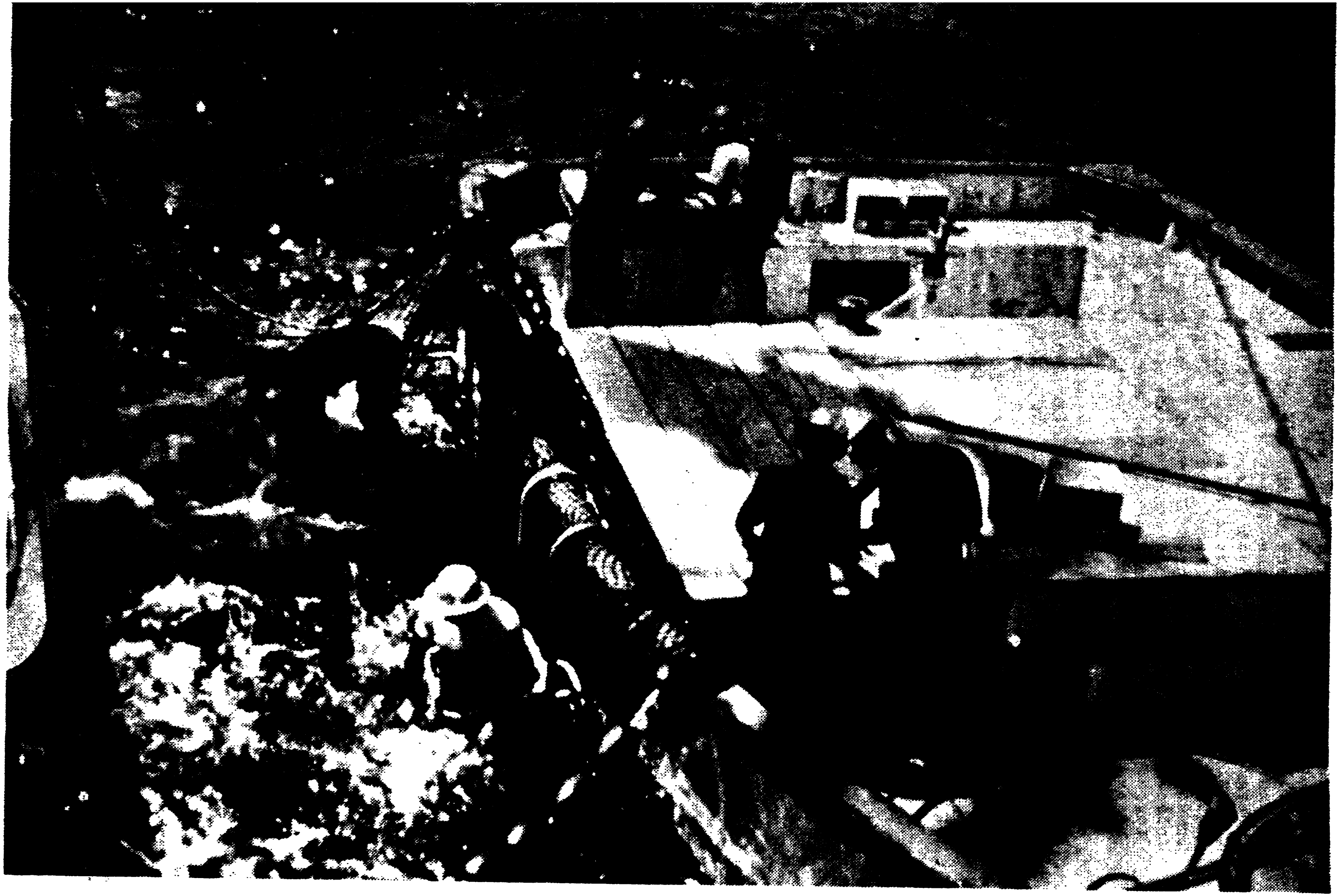

FIGURE 1. Tagging in the skiff of a purse seiner (from Bayliff, 1973).

removed, and the fish is tagged and released. The cradle used by the Inter-American Tropical Tuna Commission (IATTC) during the 1960's is shown in Figure 2. The tags are usually stored further from the cradle, however, to prevent them from being hit by the struggling fish. The sides of the cradle hold the fish in position, and also seem to reduce its struggles somewhat. It is important that the padding be covered with smooth fabric, as Bayliff (1973) showed that the return rates were higher for fish tagged in covered cradles than for those tagged in uncovered cradles. In some cases small cradles are fastened securely to some part of the boat, usually one of the rails, and in other cases they are not fastened down, and moved out of the way when they are not in use.

Large cradles are described by Kearney, Lewis, and Smith (1972) and Kearney and Gillett (1982).

> "The cradles ... were large enough so that one or two fish could be landed, unhooked and retained at one end by a tagging assistant while another was being examined, measured and tagged at the opposite end. Each cradle was on a slight incline so that fish would gently slide towards the narrow end... The frames of the tagging cradles were made from galvanised steel pipe which was securely fastened to several points on the vessel. This was essential, as both the tagger and the assistant relied on the cradle for support in rough seas... The cradle cover material was smooth to avoid abrasion of the fish, but tough enough to withstand some minor puncturing by the tagging needles. The cradle design allowed the cover, while out of use, to be rolled up and secured at the narrow end. This was useful in storm conditions" (Kearney and Gillett, 1982).

A large cradle is shown in Figure 3.

The large cradles are better than the small ones because it is easier to transfer the fish from the hook to the cradle without dropping them on the deck and because when fish come in for brief periods faster than the tagger can tag them the excess fish can be stored momentarily at the large end of the cradle. The large cradles require more deck space, however, and they cannot be easily moved out of the way when fish are not being caught, as is the case for the small cradles. In general, small cradles are useful when there is limited working space and the numbers of fish to be tagged are relatively small, but for large-scale experiments large cradles are preferable.

2.1.2.5 Chute method

Scientists of the U. S. National Marine Fisheries Service, La Jolla, California, U. S. A., have modified small cradles for tagging albacore as follows.

> "A chute 3 feet (91 cm) long is attached to the nose end of the cradle at its base with a hinge, and the nose block of the cradle is attached to the rest of the cradle with a single pivot so it can be lifted up to permit the fish to slide from the cradle to the chute. After a fish is tagged, instead of lifting it up and dropping it overboard, the nose block is lifted and the fish slides overboard through the chute, which is angled downward. This increases the speed of the tagging operation, decreases the amount of handling to which the fish are subjected, and eliminates the dropping of tagged fish on the deck, which sometimes occurred when the cradles without chutes were used. Most important, the fish enter the water head first and pointed toward the bow of the boat. Before the modified cradle came into use, when the fish were dropped overboard they entered the water at the stern of the boat in the middle of the school, and tended

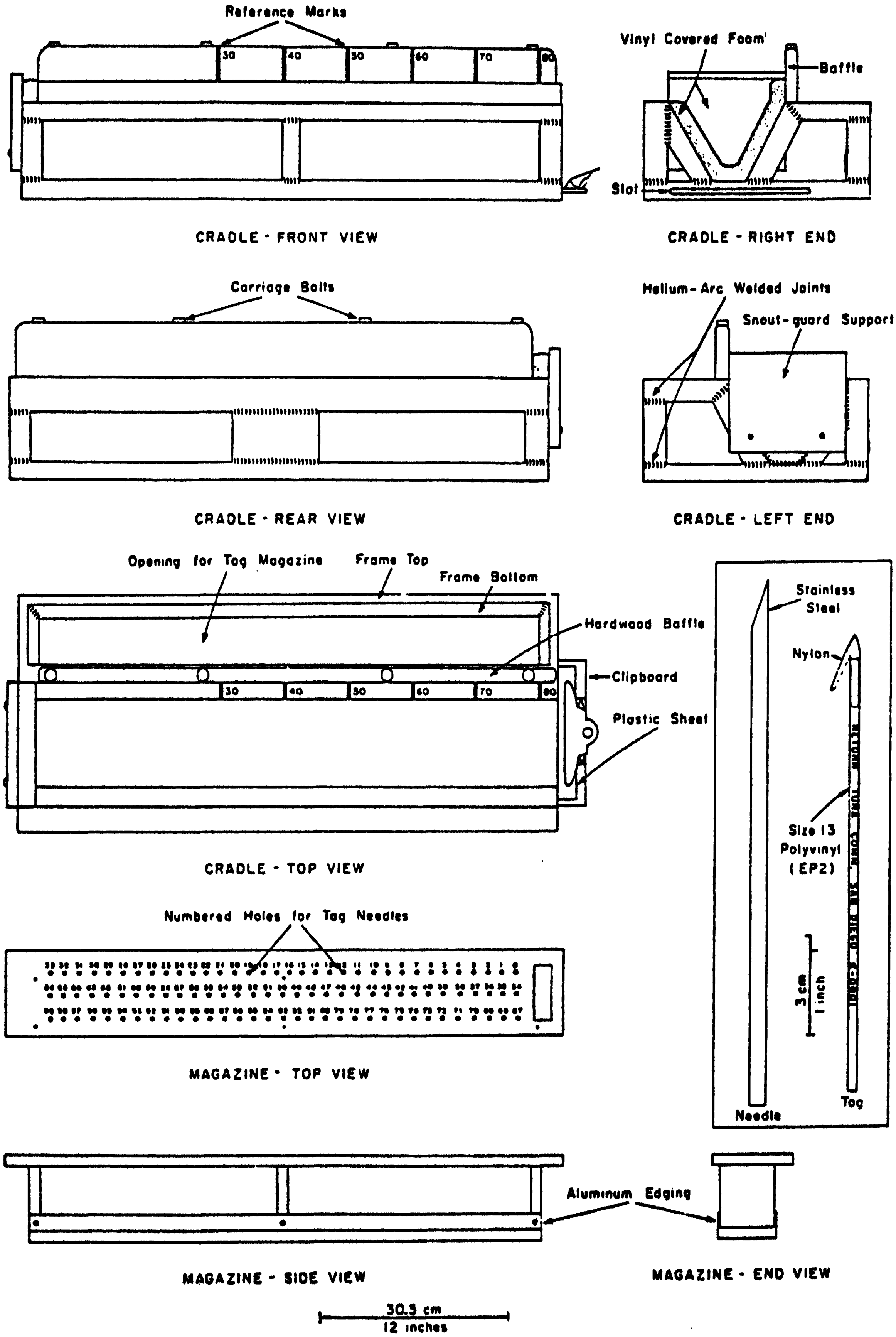

FIGURE 2. Small cradle, dart tag, and applicator (from Fink, 1965).

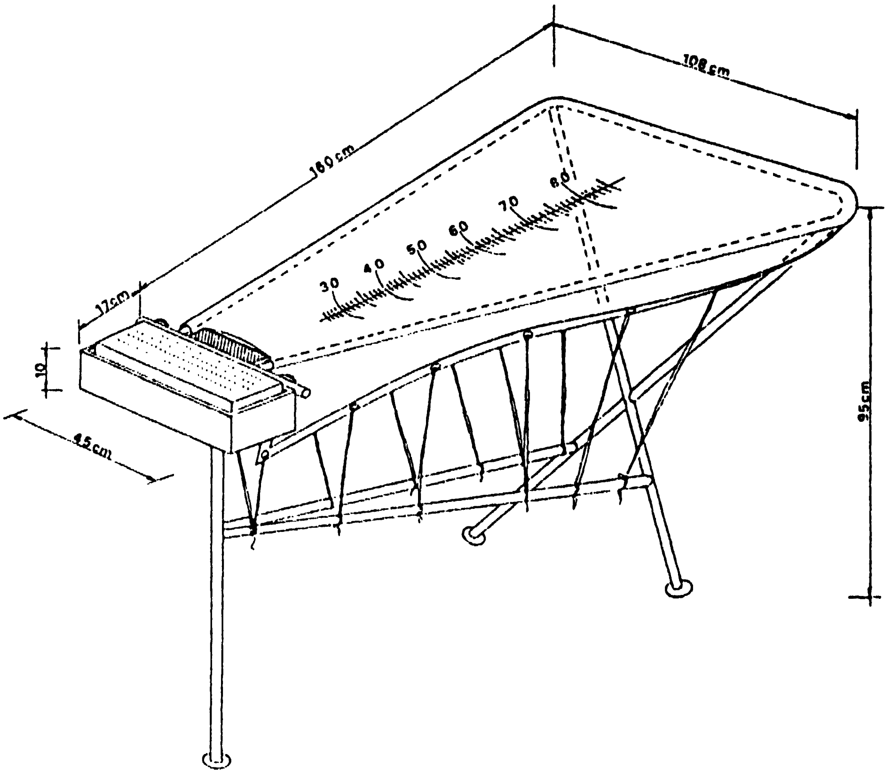

FIGURE 3. Large cradle (from Kearney and Gillett, 1982).

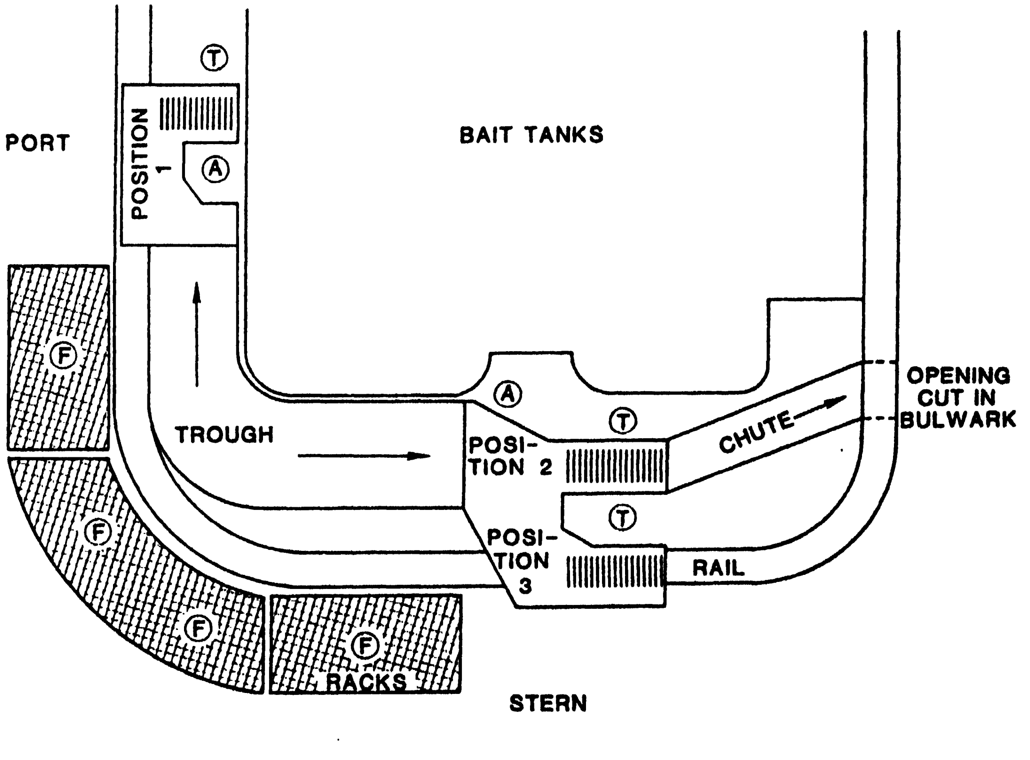

FIGURE 4. Chute system used by the IATTC (redrawn from Bayliff, 1981). The circles with F's, A's, and T's in them indicate fishermen, assistants, and taggers, respectively.

to scare the fish away, especially if they failed to enter head first" (Bayliff, 1979).

A much more elaborate chute system (Figure 4) was constructed by the IATTC.

"Essentially, fishermen in the port stern corner of the boat catch the fish and deposit them into troughs constructed of Shelterite (a strong, smooth fabric) on pipe frames. The troughs slope toward the cradles, so the fish slide in that direction. Assistants at the cradles unhook the fish, when this is necessary, and push the fish into the cradles head first and one at a time. After the fish are tagged by the taggers they are thrown overboard at positions 1 and 3 or lifted into a chute at position 2. The principal advantages to this system are: (1) the fishermen have a large target in which to deposit the fish (This is particularly advantageous when the fish are large.); (2) the proportions of fish going to position 1 versus positions 2 and 3 can be regulated by instructing the fishermen to put more or less fish into the port or stern parts of the trough, and the proportions of fish going to position 2 versus position 3 can be regulated by the assistant near these two positions; (3) the tagging positions are well removed from the fishing positions, which (a) means that the tagged fish are thrown overboard some distance from those which are being caught (Throwing the tagged fish into a biting school is believed to scare them away in some instances, especially in the case of albacore.); (b) means that the taggers can throw the fish directly over the rail, instead of over the fishermen's shoulders which occasionally results in fish falling into the racks; (c) reduces the chance of injury to the taggers due to being hit by a fish or a hook" (Bayliff, 1981).

The pads, cradles, and chutes are marked at 1-cm intervals so that the fish can be measured when they are tagged. These marks sometimes fade and wear away quickly, and when that occurs they must be renewed at frequent intervals at sea. Measurement of the fish will be discussed later.

2.1.3 <u>Tags, applicators, and holders</u>

Tunas and billfishes were tagged with loop tags (Wilson, 1953; Broadhead, 1959) during the 1950's and early 1960's, but these have now been replaced with dart tags. The most common type (Yamashita and Waldron, 1958; Fink, 1965; Kearney and Gillett, 1982) has a nylon head with a single barb (Figure 2). Most of these are about 15 cm long and 2.5 mm in diameter, but some shorter ones, with the lengths reduced to 7 to 8 cm, have been used on small skipjack (SPC, 1981). Smaller tags about 10 cm and 1.5 mm in diameter have been used for northern bluefin, <u>Thunnus thynnus</u>, 15 to 30 cm in length (I-ATTC/CIAT, 1982). and bonito, <u>Sarda chiliensis</u> (Campbell and Collins, 1975), and small skipjack have been tagged with tags about 2.5 mm in diameter shortened to about 7 to 8 cm in length (SPC, 1981). Larger dart tags, with metal or nylon heads, are used for billfishes and large tunas on sport-fishing vessels (Figure 5). Most of the tags are made of low-temperature vinyl tubing, which is attached to the nylon heads with cyanoacrylate glue or vinyl adhesive. This tubing turns brittle at temperatures below about 40°C. Since some fishing vessels freeze the fish they have caught at temperatures lower than 40°C, the tags are likely to break off the fish and be lost. A few tags have made from polyurethane, which is more resistant to breakage at low temperatures, but this material is more difficult to extrude than vinyl, and these tags were unsatisfactory (Kearney and Gillett, 1982). Tags made with polypropylene tubing have also been used (Majkowski, 1982), and these are reported to be quite satisfactory (John Hampton, personal

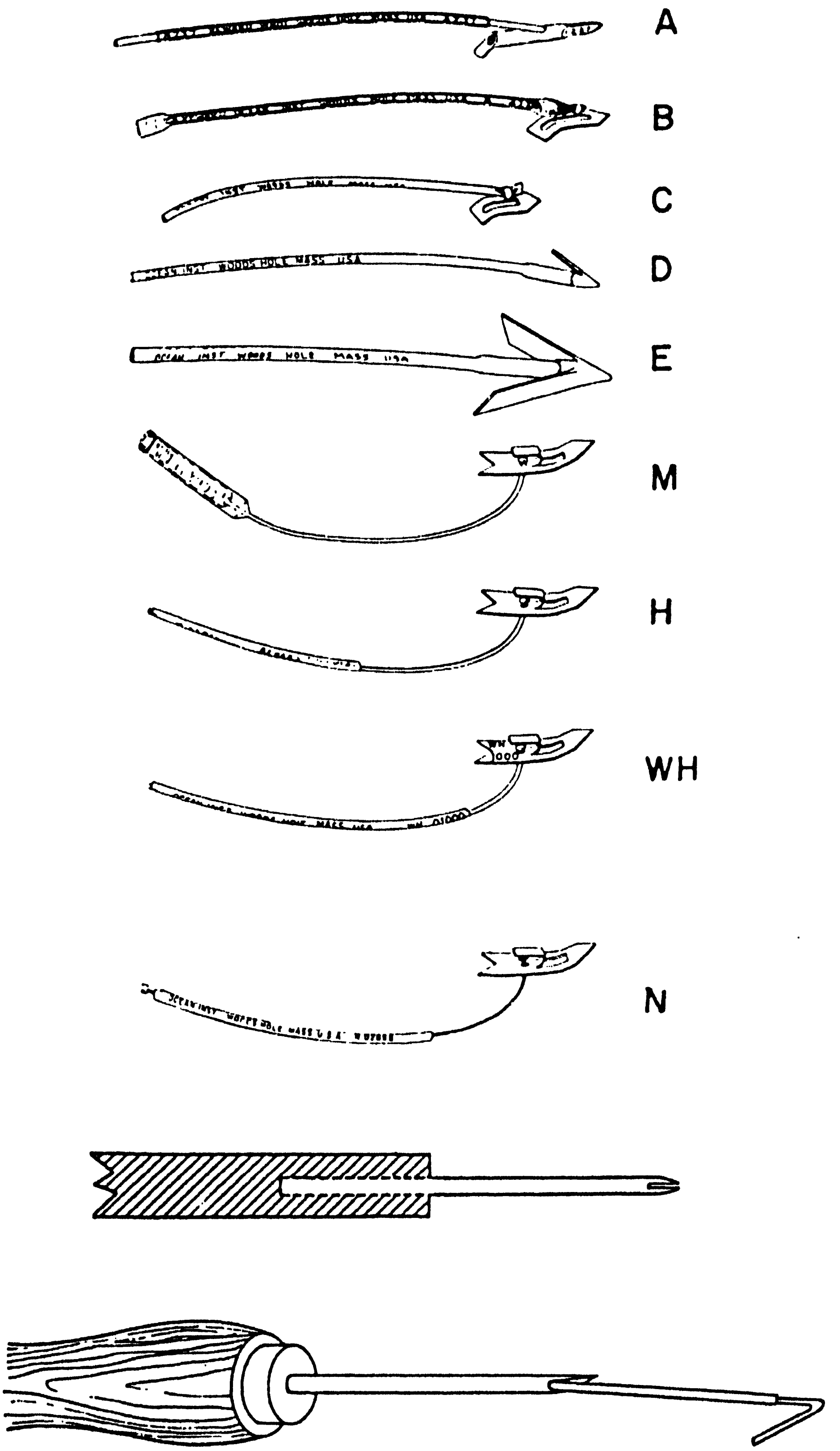

FIGURE 5. Tags and applicators used for large tunas and billfishes (from Akyüz, 1970, and Mather, Tabb, Mason, and Clark, 1974).

communication, December 19, 1985). Tags made of polyethylene tubing bonded to nylon heads have recently been introduced (Anon., 1985). Polyethylene is resistant to breakage at low temperatures and less springy than vinyl. The latter characteristic may be an advantage, as the tag may retain the configuration which causes the least resistance to the water when the fish is swimming in a straight line at its normal speed.

Most tags are yellow, but other colors have been used from time to time. Data presented by Broadhead (1959) and Blunt and Messersmith (1960) indicate that yellow tags are easier to see than red, blue, white, or clear ones. Fish which were injected with tetracycline (to be described later) have been tagged with yellow tags with the tips painted red or with red or international orange tags to let the persons who recover them know that the fish were of special interest. Tags should have the name of the organization to which they should be returned and the codes on them. The codes should be printed on both ends of the tags so that the information is less likely to be lost if the tag is broken or mutilated when it is returned. The amount of the reward, if any, should not be printed on the tags. (Rewards will discussed later.) Tags are most often coded with five digits (100,000 possible combinations), a letter and four digits (260,000 possible combinations for the English alphabet), or two letters and four digits (6,760,000 possible combinations for the English alphabet). They usually arrive from the manufacturer sorted into groups of 100, and they are almost always allocated to the various taggers at sea in those same groups. It is less confusing and more convenient for computerized analyses if these groups contain, for example, A0000-A0099, A0100-A0199, etc., rather than A0001-A0100, A0101-A0200, etc. (Kearney and Gillett, 1982).

Most nylon tag heads are manufactured or supplied by Floy Tag and Manufacturing, Inc, Arthur E. King and Company, or Riverside Molded Products, Inc. (Additional information on the manufacturers of products mentioned in this report is listed in the Appendix.) The Floy heads are slightly larger than the King and Riverside heads, and hence require larger applicators (described in the next paragraph). The King heads are slightly stiffer than the Riverside heads. Experiments performed by the IATTC in which fish were tagged with two tags, one with a King head and one with a Riverside head, showed that the tags with the Riverside heads were shed at a greater rate than those with the King heads. Metal heads are superior to nylon heads when the in-the-water tagging method is employed (Mather, Tabb, Mason, and Clark, 1974).

Dart tags of the type shown in Figure 2 are attached to the fish with applicators which consist of pieces of steel tubing slightly longer and slightly larger in diameter than the tags. These are sharpened at one end, as shown in the figure. Commercially-made heads often have an indentation in the sharpened end to accomodate the barb of the tag, but this does not seem to be necessary. It is important that the applicators be longer than the tags, because otherwise the tags will not go all the way into them when they are stored in the holders (described below) before use, and the head will be cut off when attempting to attach the tags to the fish. It is also important that the applicators be neither too large nor too small in diameter. If they are much too small the tags cannot be slipped entirely into the applicators, and if they are slightly too small the tags may be pulled out of the fish when the applicators are withdrawn. If the applicators are too large the tags are likely to fall out when attempting to attach them to the fish. In the latter case, however, they can be crimped to prevent the tags from falling out (Kearney and Gillett, 1982). Tags with Floy heads require applicators with an inside diameter of 0.150 inch (3.810 mm), while tags with King or Riverside heads require applicators with an inside diameter of 0.135 inch (3.429 mm). It is suggested that an organization which is planning to tag tunas or billfishes for the first time order its tags and applicators from the same manufacturer so as to be sure that the tags will fit the applicators.

Dart tags with steel heads are applied with applicators similar to those shown in Figure 5.

> "It is most important that the darts and streamers fit loosely on the applicators and handles. Otherwise, they may be partially or completely retracted from the fish when the applicator is withdrawn" (Mather, 1963).

Prior to use the tags are inserted into the applicators and stored in groups of 100 in holders made of fabric (Wilson, 1953) or wood (Fink, 1965; Bayliff, 1973; Kearney and Gillett, 1982). The compartments or holes in the holders are numbered from 00 to 99, and the tags are matched with these numbers. Fabric holders are suitable for small-scale tagging, as on a troller or sport-fishing vessel, but wooden holders should be used for large-scale tagging. The arrangement of Fink (1965), shown in Figure 2, is no longer used, as the fish often hit the holders, knocking applicators and tags onto the deck and injuring themselves. Up to about 30 holders are loaded with tags prior to fishing. Since the sharpened points of the applicators are exposed, all of the holders but the first ones to be used are stored in wooden boxes (open on one side, but not at the top) from which they can be easily removed.

2.1.4 Recording equipment and materials

The data corresponding to each tag which is used (location, date, species, length, remarks concerning the condition of the fish, etc.) must be recorded. A list of the data which are commonly recorded is given at the top of Table 1. Not all of these things are recorded for every fish, however. For example, if 900 fish were tagged at the same location during a short period of time by three taggers each would record one location, one date, one time, one cradle or position, and about 300 tag numbers and the corresponding lengths. The condition of the fish is not usually recorded unless the fish is wounded or mishandled (tagged too low or too high on the fish, dropped on the deck, etc.). At sea the recording is usually done in two stages, the first stage at the time the fish are tagged and the second stage at the end of the day. If small numbers of fish are being tagged the data are usually recorded on forms printed on heavy plastic attached to a clipboard. These forms have spaces numbered from 00 to 99 for recording the species, length, condition, etc., and a space at the top for recording the location, date, tag series, cradle or position, time tagging commenced, etc. If large numbers of fish are being tagged the data are recorded with small tape recorders hanging around the taggers' necks. Small plastic bags are used to prevent the tape recorders from getting wet. At the end of the day, or sooner if feasible, the data from the plastic forms or the tapes are transcribed onto permanent paper forms. These are similar to the plastic forms described above. The South Pacific Commission (SPC) prints books of forms, with white and green copies of each page and carbon paper between each pair of pages. When convenient the white copies are torn out of the books and taken to the SPC headquarters, while the green copies remain in the books aboard the tagging vessel.

Tags, applicators, and postal cards with codes matching those of the tags are issued to owners of sport-fishing charter vessels and to sport fishermen. When a fish is tagged the location, date, species, and an estimate of the size of the fish are written on the postal card and it is sent to the organization which is coordinating the program.

2.1.5 Daily routine

This account describes tagging aboard a baitboat. Large numbers of fish are often tagged in short periods of time aboard baitboats (and also purse seiners), so it is imperative that everything be well organized at all times. Tagging is usually much slower aboard most other types of vessels, so less organization is required. An adequate number of tags and

TABLE 1. Data which could be included in a release-recapture record for tagged fish.

Release data

- Cruise number
- Tag code
- Tag type
- Species
- Location
- Country in which released
- Date
- Time of day
- Length
- Sea-surface temperature
- Tagger
- Position or cradle
- Injected or not injected with tetracycline
- Condition of fish

Recapture data

- Tag type
- Most likely location
- Most likely country in which recaptured
- Most likely date
- Earliest possible date
- Latest possible date
- Length
- Condition when measured (fresh, frozen, thawed after having been frozen, etc.)
- Reliability of measurement
- Sex
- Gear
- Vessel
- Process in which recovered (fishing, unloading fishing vessel, unloading freezer ship, butchering, etc.)
- Port returned
- Regulation status
- Person handling the return data

Calculated data

- Most likely net distance travelled
- Most likely direction of movement
- Most likely days at liberty
- Least possible days at liberty
- Most possible days at liberty
- Growth

applicators should have been loaded into the holders the preceding evening. A piece of masking tape with the tag series written on it should have been stuck to the end of each holder so the tagger can quickly choose the series with the lowest codes and record which series he is using without pulling one of the tags out of its applicator. The holders should be placed in boxes near each tagging cradle or position. Each tagger, if he is using a tape recorder, should have checked it to be sure that it is working properly and has enough tape for recording. Each tagger should record the location, date, time, cradle or position, etc. Cotton or wool gloves are usually worn by the taggers and assistants during tagging to protect them from cuts and enable them to get a better grip on the fish. When large numbers of fish are tagged the hands of the persons who handle them sometimes develop a rash and blisters; thin rubber gloves worn beneath the cotton or wool gloves can prevent that. Water should be sprayed or poured over the cradles or chutes and the gloves should be thoroughly wetted just before tagging commences.

> "When hooked, fish were carefully, but without delay, raised to the cradle level ... An assistant standing next to the tagger ... directed the fish gently into the cradle while holding the fishing line. The tuna frequently became unhooked by themselves, otherwise gentle twitching on the line was normally sufficient. If the fish was deeply hooked or obviously badly injured it was quickly rejected onto the deck by the fishermen. The tagging assistant made a preliminary assessment of more subtle damage to the fish and rejected those that appeared to be injured. Care was taken not to handle the fish by the relatively fragile caudal peduncle. The assistant then slid the fish (left side up, head towards narrow end of the cradle) to the tagger, who made a final evaluation of the condition of the fish. Criteria for rejection included bleeding, except for minor hook wounds, too long spent in the cradle (more than approximately 15 seconds), rough treatment by the assistant, or serious natural injuries. The tuna was gently pushed until its snout touched the padded block at the narrow end of the cradle. Fork length (tip of snout to caudal fork) was then measured to the nearest half centimetre from the calibrations on the cradle cover" (Kearney and Gillett, 1982).

(It is more common to record the lengths in whole centimeters; the IATTC records them to the nearest centimeter and the organizations which participate in the tagging program of the ICCAT record them to the next lowest centimeter (i.e. lengths from 60.0 to 60.9 cm are recorded as 60 cm).)

> "The tag was inserted level with, or just posterior to, the secondary dorsal fin... Ideally it was positioned at an angle of 45°, or less, to the axis of the fish to minimise water resistance. Tags were inserted sufficiently deep so that the barb interlocked with the fin ray supports of the secondary dorsal fin or the neural spines, but not so deep as to cause unnecessary damage to underlying tissue. With experience the tagger could feel when the barb passed between the neural spines or fin ray supports" (Kearney and Gillett, 1982).

The rates of shedding of tags differ among taggers (Bayliff, 1973), which indicates the importance of careful placement of the tags.

> "An estimation of the quality of the insertion operation, together with any distinguishing characteristics of the fish, was tape recorded. Tagged fish were promptly returned to the water, head first, if possible" (Kearney and Gillett, 1982).

As the fish are tagged the applicators are dropped into plastic buckets

located near the cradles or positions. Sometimes a few tags are not used because the applicators containing them are dropped on the deck, the tags are accidentally cut off by the applicators when trying to tag the fish, etc. These "rejected" tags are retained in the plastic buckets.

When tagging ceases the time is recorded on the plastic forms or tapes. The plastic forms are removed from the clipboards and stored in a safe place, and the same applies to the tapes if they have been more than about half used. (It is important to remember to change the plastic forms when tagging on a school ceases, as otherwise there may later be confusion with regard to which fish were in which schools.) The used applicators are transferred to other plastic buckets for cleaning.

When another school of fish is encountered the processes described above are repeated.

The above description applies also to tagging aboard a purse seiner. In addition, however, on purse seiners a timing clock has sometimes been used, setting it to ring at 10-minute intervals, and these times have been recorded. This has been done to determine the relative survival rates of fish confined in the net for different periods of time.

The pads, cradles, or chutes should be calibrated or adjusted at frequent intervals. If they are to be calibrated the distance from the nose line or block to various length intervals marked on the pads, cradles, or chutes, for example, 30, 40, 50, 60, and 70 cm, are measured and recorded. This information is eventually used to calculate linear regressions for estimating the lengths of the fish at release, adjusted for shrinkage or stretching of the pad, cradle, or chute covers. If they are to be adjusted the distance from the nose block to a length interval near the middle of the cradle or chute is measured, and if the distance does not match the length interval on the cradle or chute the nose block is adjusted accordingly.

The applicators are cleaned by soaking them in a solution of enzyme detergent and fresh water for about 1 hour, and then in a solution of household bleach (sodium hypochlorite) for at least 20 minutes, and then rinsing them with water. If enzyme detergent is not available that step can be omitted. The applicators can then be reused.

At the end of the day more holders are loaded with tags and applicators for use the following day. The data on the plastic forms or tapes are recorded permanently on the paper forms (Figure 6) and the plastic forms are cleaned or the tapes are rewound for use the following day. No paper form should contain data for more than one school of fish, as there is room at the top for only one location, date, etc., and it is illogical to risk confusion and errors to save paper. The rejected tags are compared with the paper forms, and any corrections which are necessary are made to the forms. Then the rejected tags are destroyed.

Tape recorders are a great convenience, but if great care is not taken at every stage large amounts of data can be lost. Good quality recorders, tapes, and batteries should be used, and all should be in good condition. Each tagger must be sure that there is sufficient unused tape in the recorder at all times, and he must be sure that the tape recorder is turned to "record" when he is speaking into the microphone and that it is turned off when there is no need to record anything. (Voice-activated tape recorders do not work well when tagging fish because there is so much extraneous noise.) The status of the tape recorder should be checked at frequent intervals during tagging, as sometimes it may be switched out of the "record" mode accidentally due to a worn switch or a fish which hits the tagger in the chest.

Date	28 / 12 / 79 (D M Y)	Time	12.15	Tag Series	C11901
Position	Lat 8°53'S / Lon 140°21'W	School No.	1	Cruise No.	
		Temp.	28.8	Skipjack	100
Tagger	JNI	Cradle	PS	Yellowfin	0

No	LCF		No	LCF		No	LCF		No	LCF	
01	47		26	47		51	44		76	45	
02	46		27	47		52	47		77	50	
03	48		28	48		53	46		78	49	
04	45		29	48		54	46		79	47.5	
05	47		30	47		55	47		80	46	
06	44		31	49		56	47		81	47.5	
07	48.5		32	46		57	48		82	44	
08	46		33	46		58	47		83	46	
09	48		34	46		59	48	TS	84	47	
10	48		35	45		60	47		85	43	
11	45		36	45		61	49		86	49	
12	45.5		37	46		62	46.5		87	47.5	
13	45		38	43.5		63	48		88	47	
14	47		39	46		64	44.5		89	48	
15	48		40	45		65	47		90	46.5	
16	44		41	46		66	48		91	48	
17	46		42	46		67	43.5		92	48	
18	46		43	49		68	46		93	48	
19	47	TL	44	46		69	46	SB	94	46	
20	47		45	45		70	47		95	46.5	
21	46		46	45.5		71	47		96	46	
22	46		47	45		72	49	TL	97	45	
23	46		48	47		73	45.5		98	44	
24	48		49	45		74	43	TH	99	46	
25	48		50	47		75	46		00	48	

Cruise	1089	Tagger	Schaefer	Page	35	YF	SJ	Other
Date	4-14-80	Position	5°22'N-85°04'W	Total for page		9-2	37	BSJ 1
Set number		Treatment	SPC CRADLE* STEIN	Total for set				
Area		Water temp.	85°F	Total to date				

Tag number	Length YF	Length SJ	Length Other	Remarks	Tag number	Length YF	Length SJ	Length Other	Remarks
Q22 00		50			50		48		
01				M	51		51		
02		46			52				
03		48			53	46			
04		48			54				
05		49			55	52			
06					56				
07	47				57	43			
08					58		48		
09	45				59		52		
10					60		53		
11	46				61		51		DD
12					62				
13	42				63	56			
14					64				
15	44				65	U			
16					66				
17	43				67	48			
18		45			68				
19		50			69	51			
20		48			70		54		
21		49			71		53		
22					72				
23	48				73	54			
24		52			74				
25		49			75	54			
26					76				
27	40				77	54			
28		49			78		41		
29		50			79		51		
30		47		TL	80				
31		48			81	41			
32					82				
33	49				83	47			
34					84		52		
35	41				85		52		
36					86		52		
37	48				87		50		
38		48		TL	88				
39	39				89	50			BL
40					90		49		
41	54				91			45	BSJ
42					92		49		
43	U				93		42		DD
44		U			94				
45	42				95	54			
46		48			96				
47		54			97	40			Jig-caught
48		53			98				
49		47		BL	99	37			BL

FIGURE 6. Paper forms used by the SPC (left; from Kearney and Gillett, 1982) and IATTC (right) to record release data. The abbreviations stand for the following: TL, tagged low; TS, tagged too shallow; SB, shark bite; TH, tagged high; M, missing; U, unknown; BL, bleeding; DD, dropped on deck; BSJ, black skipjack.

2.1.6 Rates of tagging and numbers of fish which can be tagged per day

The following rates of tagging fish with dart tags have been measured:

Species	Size	Method	Time	Reference
skipjack	2-25 lb	winging	as little as 4 sec	Yamashita and Waldron, 1958
tunas	up to 6.75 kg	small cradle	7-12 sec	Fink, 1965
yellowfin	greater than 25 lb	deck	about 1 min	Fink and Bayliff, 1970
skipjack		large cradle	within 10 sec	Kearney, Lewis, and Smith, 1972
southern bluefin			within 30 sec	Hynd and Lucas, 1974
yellowfin	greater than about 80 cm	deck	20-30 sec	Anon., 1981a: 26-27
skipjack		large cradle	3 sec	Kearney and Gillett, 1982
southern bluefin	47-89 cm	large cradle	10-12 sec	Williams, 1983

The maximum number of fish tagged on a baitboat in one day is 3,689 (all skipjack, average length about 48 cm; Argue and Kearney, 1983). The equivalent figure for a purse seiner is 1,131 fish (all yellowfin, average length about 75 cm; IATTC Cruise 1055, October 30, 1969).

2.1.7 Double tagging

Tunas are double tagged for at least three reasons. First, information about the effects of tagging on the mortality and growth can be obtained by comparing the return rates and growth rates of single- and double-tagged fish, *e.g.* if the return rates or growth rates for the double-tagged fish are lower than those for the single-tagged fish the tags are probably detrimental (I-ATTC/CIAT,1984:31-32). Second, comparison of the return rates of single-tagged fish and of double-tagged fish with one or two tags retained makes it possible to estimate the rates of shedding of the tags (Bayliff and Mobrand, 1972; Laurs, Lenarz, and Nishimoto, 1976; Baglin, Farber, Lenarz, and Mason, 1980; Kirkwood, 1981; Wetherall, 1982). Third, greater return rates, especially for fish at liberty long periods of time, are often realized when the fish are double tagged (Hynd, 1969; Bayliff, 1973).

The IATTC has double tagged large numbers of yellowfin and lesser numbers of skipjack and northern bluefin. The tags are placed on opposite sides of the fish, one about 1 cm anterior to the other. The taggers do not try to insert the two tags simultaneously, as this can result in one or both of them being too shallow or too deep. They are instructed to pair the tags so that the lower of the two numbers is an even number, i.e. A3900-A3901, A3902-A3903, etc., rather than A3901-A3902, A3903-A3904, etc. The holders and the plastic and paper forms for recording the data (described previously) have the numbers paired in the manner just described (Figure 6). This helps prevent the tagger from getting the numbers mixed up when he is tagging. The SPC has double tagged skipjack, inserting both tags on the same side of the fish. These are inserted either individually or both at the same time.

"In the second method, 'rubber-double tagging', pieces of strong, stiff rubber (actually cut from an old conveyer belt) were used to join pairs of applicating needles together. One needle of each pair was approximately 1.5 cm higher than the other to permit simultaneous insertion of two tags at the proper angle relative to the tuna body... Using this technique, fish could be double tagged virtually as quickly as they could be single tagged" (Kearney and Gillett, 1982).

2.1.8 Antibiotics for prevention of infection

Bayliff (1973) sprayed the tips of about half the applicators and tags used on one cruise with "oxytetracycline hydrochloride equivalent to 3.5 mg per g, 1.2 mg per g of hydrocortisone, and 1,200 units of polymyxin B as the sulfate." The return rates for the fish (yellowfin) with the sprayed and unsprayed tags were not significantly different. Majkowski (1982) stated that southern bluefin, *Thunnus maccoyii*, "tagged during the early 1960's were injected with an antibiotic to help combat tag shock, handling and infection."

2.1.9 Lactic acid and sodium bicarbonate

When fish are handled while being tagged the lactic acid levels in their blood may increase, which leads to mortality (Barrett and Conner, 1962 and 1964). In humans the buildup of lactic acid in the blood is treated with injection of sodium bicarbonate. Graf, Leach, and Arieff (1985) demonstrated that such therapy is detrimental to dogs, however, and the same may be the case for fish.

2.1.10 Tetracycline injection

Tunas and billfishes are sometimes injected with tetracycline at the same time that they are tagged to gain information on the meaning of the natural marks formed in the various hard parts (otoliths, vertebrae, spines, etc.) of the fish which could be used for age determination. Veterinary-grade oxytetracycline hydrochloride solution (100 mg oxytetracycline base as oxytetracycline HCl per ml) is used for this purpose. Tetracycline which has exceeded its expiration date as an antibiotic is also ineffective as a marking agent. The tetracycline is incorporated into the peripheries of the otoliths (and probably the other hard parts) within 24 hours. When a fish is recovered and the otoliths are examined under ultraviolet light the tetracycline mark can be seen and the number of natural marks between the tetracycline mark and the edge of the otolith can be counted and correlated with the time elapsed between tagging and recapture.

The following amounts of tetracycline have been used by various workers:

Species	Size	Amount	Reference
yellowfin	42-95 cm (1.5-17.4 kg)	1.25 ml	Wild and Foreman, 1980
skipjack	41-61 cm (1.3-5.0 kg)	1.25 ml	Wild and Foreman, 1980
yellowfin	42-124 cm (1.5-38.8 kg)	1.25-3.75 ml	Anon., 1981a: 26-27
skipjack	49-62 cm (2.4-5.3 kg)	1.25 ml	Anon., 1981a: 26-27
northern bluefin	15-28 cm (0.05-0.44 kg)	0.1-0.2 ml	Anon., 1982: 53
albacore	51-85 cm (3.3-14.7 kg)	1.5 ml	Laurs, Nishimoto, and Wetherall, 1985

The fish were all injected intermuscularly, the small to medium fish being given a single injection lateral to the first dorsal fin and the large ones two or three 1.25-ml injections in various locations. The injection equipment used in the yellowfin and skipjack experiments consisted of an 18-gauge, 1.5-inch (38-mm) needle attached to a continuously-dispensing, adjustable-capacity (up to 4 ml) Solvent Minipet syringe (Manostat catalogue number 71-510-040; the address of the company is given in the Appendix) which was connected with Tygon tubing to a Nalgene container of tetracycline carried in a backpack. The valve components (Manostat catalogue numbers 91-015-179 and 91-061-290) were made of Teflon, as swelling problems are encountered with rubber. Since tetracycline is photolytic, and the surface of the fluid can thicken if exposed to air or high temperatures, the Nalgene container was wrapped in a urethane foam blanket. At night, and during periods of inactivity during the daytime, the entire assembly was kept in a refrigerator Alternately, if the fish come aboard the boat slowly, disposable single syringes preloaded with the proper amounts of tetracycline can be substituted for the continuously-dispensing system.

The injection with tetracycline apparently does not affect the survival of yellowfin or skipjack, as the return rates of injected and control fish are not significantly different (Wild and Foreman, 1980). Injection is time-consuming, however, so in most circumstances it will result in less fish tagged.

2.2 Recaptures, recoveries, reports, and returns

The following terminology, from ICNAF, 1961: 46-47, is used in this report:

"recaptures: the (number of) tagged fish caught;
recoveries: the (number of) tagged fish detected, by fishermen or in any other way;
reports: the (number of) tagged fish concerning which any information reached the tagging organization sufficient to establish that they have been recovered;
returns: the (number of) reported tagged fish or tags which are eventually returned to the tagging organization, or the existence of which is fully authenticated."

When a tagged fish is recovered the fish with the tag(s) attached to it should be returned to a representative of a fishery organization who can measure the fish and take hard part samples, etc., if requested, before returning the fish to its owner. In many cases, however, the tag(s) is (are) removed and returned without the fish. In the following account the word "tag" should be understood to mean "tag(s) or tagged fish" when

appropriate. Tags are recovered by fishermen, unloaders, cannery workers, etc., most of whom do not know what information is required and are unwilling to go to much trouble to ensure that the tag and the pertinent information go to the organization which tagged the fish. Therefore the organizations must make it as easy as possible for the persons who recover the tags to return them with the proper information. A person who recovers a tag should be able to return it to a readily available person who questions him about the origin of the tag, measures the fish, etc., and pays the same reward regardless of which organization tagged it. There should be one or more persons in every port where tunas or billfishes are handled who accept tags and information and pay the rewards. There are persons in most of the major tuna ports who collect statistics, make logbook abstracts, measure fish, etc., and processing of tags is usually included in their duties. In smaller ports representatives of local fisheries organizations or employees of the local fish handling facilities can handle this job, provided they are properly instructed. These persons should be given written instructions concerning the data which are needed and, if necessary, money in advance to pay for the tags.

The best way to handle the instructions is to prepare envelopes with spaces to be filled in by the person who receives the tags and an explanation of how to fill in the spaces printed on the backs. The information which could be written on the envelopes is listed in Table 2. The length of the fish is nearly always preferable to its weight, since the fish are measured, not weighed, when released and since the great majority of growth studies are carried out with length data, rather than weight data. Weight data furnished by the person returning the tag can be useful in two ways, however. First, if that person has actually weighed the fish and there are few or no data on lengths of tagged fish which have been at liberty for approximately the same length of time as the fish in question, the weight can be converted to a length and used just as if the fish had been measured. Second, if the person claims to have weighed the fish or estimated its weight, but the weight is much different from what would be expected from the length at release and time at liberty, it would indicate that the other data furnished by that person may be unreliable. Some of the information listed in Table 2 may seem unnecessary, but experience has shown that it can be useful for discovering the truth when part of the information furnished is erroneous. The person who fills in the information on the envelopes should qualify the information he writes on the envelopes to some extent; for example, if the person who returns the tag to him does not furnish the fish, but furnishes an estimated or measured length, "estimated by finder" or "measured by finder" should be written after the length, as it is important that the persons who later process the data can distinguish accurate data from approximate data.

Recapture data similar to those listed in Table 1 must be inferred from the data written on the tag return envelopes. In some cases these inferences will be made by the person to whom the tag is returned or his supervisor, and in other cases they will be made by the person in charge of the tagging program or someone working closely with him. For example, when an IATTC tag is returned to an IATTC employee at a cannery by an unloader or cannery employee the IATTC employee makes no attempt to assign a location or date of recapture to the fish from the vessel name, well, and date of recovery, as the person in charge of the tagging program has access to all information required to make those inferences. When an IATTC tag is returned to a Far Seas Fisheries Research Laboratory (FSFRL) employee in Japan, however, a FSFRL employee writes the location and date of recapture on the envelope. It is important that original information and inferences drawn from the original information and written on the envelope be distinguishable. For example, the tag may have been returned by an unloader who said that he recovered it from a 10-kg yellowfin in the port-5 well of a certain vessel on a particular date. The person to whom the tag is returned may know from the vessel's logbook that most of the fish in that well were caught at a particular location on a particular date, and he

TABLE 2. Data which could be written on a tag-return envelope.

Name and address of person returning the tag

Tag code (or codes if two tags were attached to one fish)

Species

Length, weight, or both

Condition when measured or weighed (fresh, frozen, thawed after having been frozen, etc.)

Sex

Process when recovered (fishing, unloading fishing vessel, unloading freezer ship, butchering, etc.)

If recovered on a fishing vessel at sea:
- Name of vessel and type of gear
- Location recaptured
- Date recaptured
- Port and date returned

If recovered on a fishing vessel while being transferred to a freezer ship or cannery:
- Name of fishing vessel and type of gear
- Well in which stored
- Port and date recovered
- Port and date returned

If recovered in a cannery after being transferred from a fishing vessel:
- Same as above

If recovered on a freezer ship while being transferred to a cannery:
- Name of freezer ship
- Name of fishing vessel and type of gear (if available)
- Port and date recovered
- Port and date returned

If recovered in a cannery after being transferred from a freezer ship:
- Same as above

Amount of reward paid

Name of person to whom tag was returned

Remarks

may have a length-weight conversion table with which he is able to convert weight to length, but it should be clear that the vessel, well, date of recovery, and weight data are original information and the location, date of recapture, and length data are inferences drawn from the original information.

The organization or person to whom the tags and information are returned should send them promptly to the organizations which have their names printed on the tags. Before sending them, however, it is advisable to make photocopies of each envelope in case they are lost in transit.

The rewards should be uniform within regions, regardless of which organizations tagged the fish. (It would be better if the rewards were uniform worldwide, but this is not feasible, due to the fact that different rewards are necessary in different regions to achieve the same The various organizations tagging tunas and billfishes in a region should agree on a reward for that region, and that reward should continue to be paid by all of them until they agree to change it. For example, the reward might be $2 in the eastern Pacific and $5 in the western Pacific. An eastern Pacific fisherman who caught a fish tagged off Japan by the FSFRL and returned it to an IATTC employee would receive a $2 reward from the IATTC and no additional reward from the FSFRL. Likewise, a western Pacific fisherman who caught a fish tagged off North America by the IATTC and returned it to a FSFRL employee would receive a $5 reward from the FSFRL and no additional reward from the IATTC. If substantial numbers of tags of Organization A are returned to employees of Organization B, but relatively few tags of Organization B are returned to employees of Organization A, Organization A could reimburse Organization B for the difference in the amounts of money dispensed. The principles established by the ICCAT in regard to reimbursement to organizations which have paid the rewards for tags of other organizations are discussed by ICCAT (1983: 214-219).

The amounts of the rewards should not be printed on the tags, as this could cause problems when fish tagged in one region are returned in another. In addition, it could cause problems if it was decided to change the amount of the reward, as tags with the old amount printed on them might continue to be recovered after the reward had been changed.

When fish are double tagged the reward for both tags should be twice the reward for one tag, as otherwise some persons recovering fish with double tags might return them separately on different dates, giving false information for one of them. It has been the usual practice to pay the full reward when little or no information is furnished with the tag or the information which is furnished is believed to be false, because otherwise the persons who return tags without proper information might make up reasonable-sounding information to be sure that they would get the full rewards.

Sometimes bonuses are offered if the fish is returned with the tag. It is understandable that this has been done, as some experiments, such as those involving tetracycline injection, would not be successful if the tags were not accompanied by the fish. It should be recognized, however, that such a system tends to make the persons who return the tags think that when the bonus is not offered the organization which tagged the fish has no need for the fish, which could result in less fish being returned with the tags for experiments for which bonuses are not offered.

In addition to rewards, some organizations have conducted lotteries, each tag giving the person who returns it one chance to win the lottery. Ideally the lotteries should be regional, rather than organizational, and any tag from a fish caught in the region should be worth one chance to win the lottery. This situation exists for fish caught in the Atlantic Ocean; there are two annual ICCAT lotteries, one for tropical species and one for temperate species.

Virtually all the organizations which have tagged tunas or billfishes have prepared posters specifying the amounts of the rewards and describing the kinds of information needed. The poster shown in Figure 7 describes what information is needed quite clearly. Ideally, however, at the bottom there should be a place for a sticker or stamp giving the name, address, and telephone number of the person in that port to whom tags can be returned. The name and address of the organization which tagged the fish should be printed in smaller letters for use only when, for some reason, the person who recovers a tag cannot locate the local representative. There is no need for more than one type of poster in any region, except to accomodate persons speaking different languages, as all posters used in a region should request the same information and specify the same reward. In addition to displaying posters, the IATTC often distributes handbills describing the program and what information is needed to fishermen, unloaders, and cannery workers.

2.3 Handling the data

2.3.1 Release data

The paper forms or postal cards with the release data described previously are eventually brought back or mailed to the headquarters of the tagging organization. At that time the data should be summarized and the summaries sent to persons who are responsible for collecting tags from the persons who recover them and who are likely to encounter substantial numbers of tags. Such summaries are extremely useful to such persons, as having the summaries makes it much easier for them to tell when information furnished by the persons who return the tags is likely to be false. When they question the persons who furnish suspect information immediately the latter may gradually learn that they are expected to furnish complete and accurate information. The ICCAT assembles lists of the tag series used or likely to be used by all organizations which tag tunas and billfishes in the Atlantic Ocean and distributes them to organizations and persons who have need for this information.

It is highly desirable that all the release data be converted to numerical codes and stored as computer records, and that at least one copy of the data be copied onto magnetic tapes or floppy disks which are kept in another building. If the data are stored as computer records each tagged fish constitutes one record. Release data which could be included in a record are shown in Table 1. (When fish are double tagged the SPC makes separate records for each tag, but the IATTC makes only one record, using only the lower of the two codes. For tag type it uses 1 for streamer, 2 for dart, 3 for streamer plus dart, and 4 for double dart.) The original paper forms or postal cards should be retained even if computer records are made.

2.3.2 Recapture data

When the tag return envelopes are received by the organization which initiated the experiments the data must be recorded in a standard format. The envelopes will probably not have all the recapture data (see Table 1) which are to be recorded, so the data which are missing must be added or substituted for the original information. For example, if the envelope contains the vessel name, well, and date of recovery the location and date of recapture must be inferred from this information. If large numbers of returns are involved it is virtually imperative that the release and return data for the tags which are returned be converted to numerical codes and stored as computer records. This is because, in addition to recording the location, date, length at recapture, etc., the net distance moved, direction of movement, days at liberty, and growth should be calculated, and it is extremely time consuming to do this without a computer. The SPC transfers the return data directly from the handwritten form in which it is received to its computer records for fish which have been released.

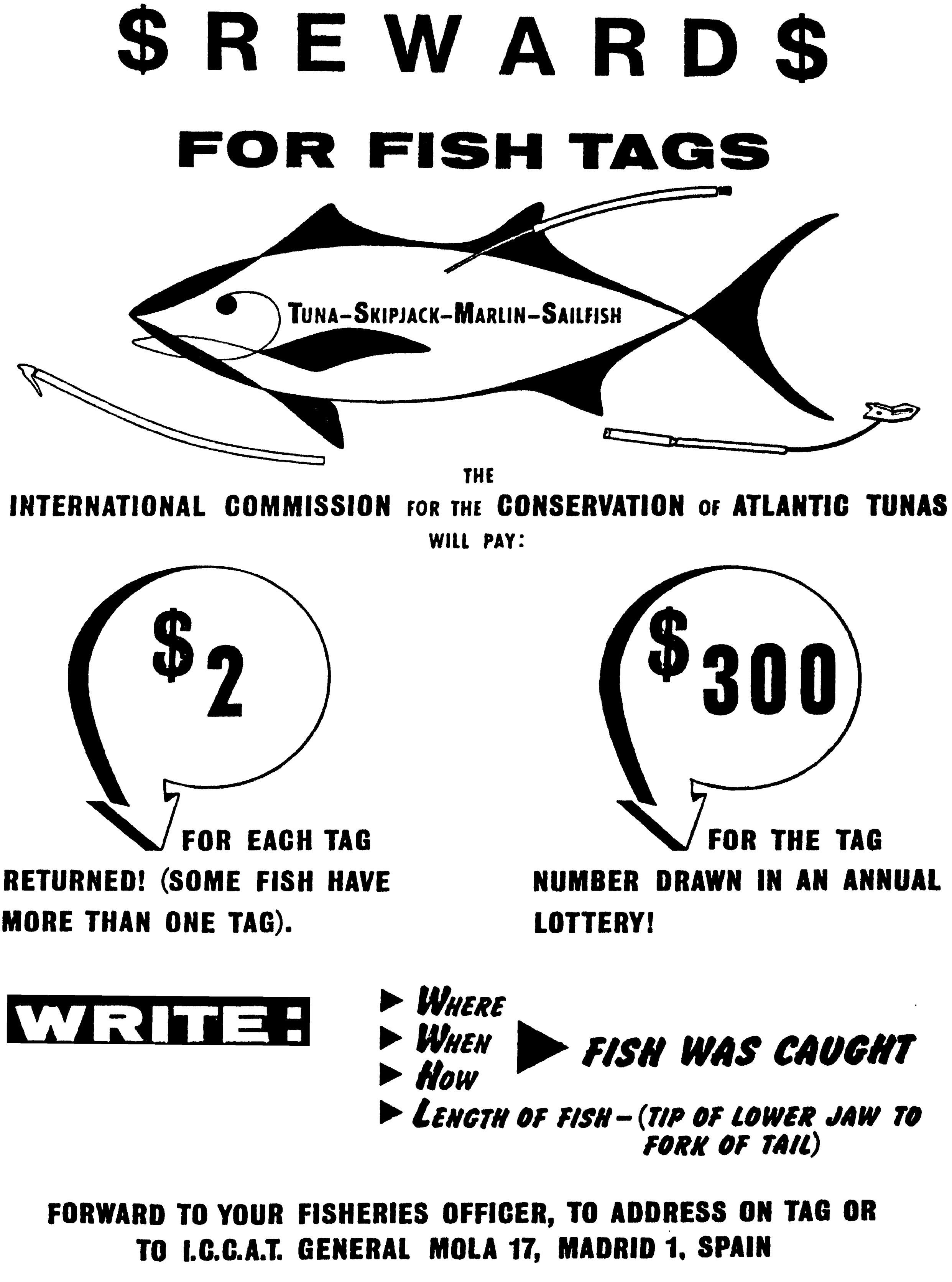

FIGURE 7. Tag return poster used by the ICCAT.

Letters of acknowledgement to the persons who return the tags are written by the computer. The data are copied onto magnetic tapes at frequent intervals, and copies of the tapes are stored in another building. The IATTC does not make computer records for all the fish which have been released. When a tag is returned someone records the release data (from the paper forms prepared at sea) and the recapture data (from the envelopes described previously) on the form shown in Figure 8 (with two carbon copies). The original of this form (without the computer codes) is sent to the person who returned the tags, the first copy is used to prepare the computer records and then stored permanently, and the second copy is stored temporarily in another building until the computer records have been transferred to magnetic tape and stored in another building. Recapture data which could be included in a record are shown in Table 1. (If the fish was double tagged and both tags are recovered the SPC makes one record for each. The IATTC makes only one record for each double-tagged fish, however; if a fish which was originally double tagged retains only one of its tags the numerical codes for release tag type and recapture tag type are different.) The tags, original handwritten return data, and intermittent stages such as the form shown in Figure 8 should be retained even if computer records are made.

2.3.3 Checking the data for errors

There are various ways in which the data can be checked for errors. Majkowski (1982) describes the procedures used to check the data for southern bluefin tagged by the CSIRO Marine Laboratories of Australia. Suitable methods equivalent to these should be employed by all organizations handling tag release and return data.

2.3.4 Additional ICCAT procedures

The ICCAT has assembled centralized tag release and return files and catch and fishing effort files for the Atlantic Ocean, so that analyses of the combined data from tagging experiments initiated by several organizations can be carried out.

3. ULTRASONIC TELEMETRY

3.1 General

The objective of this section is to give an overview of modern ultrasonic tracking techniques currently employed in the study of pelagic fish. Detailed reviews of previous results are not included, nor are comprehensive descriptions of the physical and electromechanical constraints on ultrasonic telemetry, as these are available elsewhere (Stasko and Pincock, 1977; Mohus and Holand, 1983).

The advent of ultrasonic telemetry has opened a window into the world of deepwater fish that allows investigators to monitor fish behavior and physiology in the wild. The primary attribute of ultrasonic telemetry is that it allows researchers to follow the fine-scale horizontal and vertical movements of the fish carrying the transmitter (tag). By using directionally sensitive hydrophone systems skillful operators can keep the tracking vessel within the range of the tag and thereby construct a plot of the movements of the target fish for a period of several days. Valuable additional behavioral data concerning the fish's vertical movements can be obtained by incorporating a pressure sensor in the design of the transmitter. The pressure sensor modifies the transmitted signal so that a single output channel can relay both directional and depth information.

More recent refinements of ultrasonic transmitters have been developed to monitor physiological parameters in addition to basic information concerning the fish's position. Muscle temperature and water temperature can be encoded in the transmitter signal, as can a variety of muscle

INTER-AMERICAN TROPICAL TUNA COMMISSION
Scripps Institution of Oceanography
La Jolla, California, 92037

Dear sir

Thank you for returning this tag to our representative. The information on the movement and growth of the fish is shown below. We will be happy to furnish additional information on our tagging program or other phases of our research at any time. This can be obtained by contacting our waterfront representatives or by visiting or telephoning our La Jolla or San Pedro offices.

Estimado señor

Le agredezco que haya devuelto esta marca a nuestro representante. La información sobre el desplazamiento y crecimiento del pez se indica más adelante. Nos complacería suministrar en cualquier momento más información sobre nuestro programa de marcado u otras fases de nuestra investigación. Este puedo obtenerse por medio du nuestros representantes que trabajan en el puerto o al visitar o telephonear a nuestras oficinas de La Jolla o San Pedro.

RELEASE - LIBERACION		RECAPTURE - RECAPTURA	
Cruise number	(1-4)	Date	(38-43)
Tag number	(5-10)	Area	(44-53)
Species	(11)	Length	(54-57)
Tag type	(12)	Days free	(58-61)
Date	(13-18)	Miles travelled	(62-65)
Area	(19-28)	Direction of movement	(66-68)
Length	(29-32)	Growth	(69-72)
Temperature	(33-34)	Tags retained	(73)
Miscellaneous codes	(35-37)	Vessel	(74-76)
		Place found	(77)
		City or country found	(78)
		Regulation status	(79-80)
		Handled by	

FIGURE 8. Form used by the IATTC to record release and recapture data for tags which are returned.

movement data (electromyograms--EMGs) such as heart rate, tail-beat frequency, and opercular movement. Transmitters are being developed to transduce and relay swimming speed and compass orientation.

The basic design of an ultrasonic transmitter must include a power source (batteries), an electronic device to convert the battery power, and a resonating ceramic cylinder to produce the ultrasonic signal. These components are permanently imbedded in resin. Lower-frequency wave lengths propagate more efficiently through water, but lower frequencies require larger resonators which quickly become too cumbersome for the fish to carry. Also, the power output and life span of the transmitter must be balanced to keep the size and weight of the batteries within reasonable bounds. Most researchers have settled on transmitters operating between 30 and 150 khZ with expected lifespans of between 3 and 20 days and horizontal ranges between 800 and 3,000 m. Transmitters for use on large fish, such as sharks, can be designed to carry larger batteries and have greater ranges than systems designed for use on smaller fish, such as skipjack or salmon. Most transmitters use a pulsed signal carried on the selected wave length (*e.g.* 50 khZ) at about one pulse per second. In depth-sensitive transmitters this rate increases as the fish goes deeper or, as in the case of temperature monitoring, gets warmer. A pulsed signal uses less energy than a continuous transmission. If the fish stays deep (or warm) the transmitter will pulse at a greater rate, which will reduce the life of the battery. Hydrophones to receive and transduce the ultrasonic signal back into electronic form are matched to the frequencies they are designed to detect and the amplifier-receivers that process the signal are similarly tuned to match the carrier frequency of the transmitted signal.

3.2 Fishing techniques

A wide range of fishing techniques has been employed to obtain fish for tracking. Free-swimming swordfish, *Xiphias gladius*, have been harpooned with transmitters (Carey and Robison, 1981). Swordfish, northern bluefin, and bigeye, *Thunnus obesus*, have been tagged following capture by longline gear (Carey and Lawson, 1973; Carey and Robison, 1981). Albacore used in tracking experiments have been caught from baitboats using hooks baited with anchovies (Laurs, Yuen, and Johnson, 1977). Most fish, however, have been caught using variations of trolling techniques. Marlins, yellowfin, skipjack, and bigeye have all been captured for tracking using trolling methods (Yuen, 1970; Yuen, Dizon, and Uchiyama, 1974; Dizon, Brill, and Yuen, 1978; Yonemori, 1982; Holland *et al.*, in press). In all cases it is essential to use single (often barbless) hooks that inflict minimal injury and which can be easily removed or which will fall out following severance of the leader. Trolling lines should be set with light drag to minimize jaw injury at the moment of the strike. Handling should be done with bare hands and plastic-lined, foam-padded cradles to minimize the removal of mucous from the fish's surface.

3.3 Transmitter attachment

Three types of transmitter attachment have been used on pelagic fish, the "harpoon" technique, stomach insertion, and intramuscular sutures. The harpoon technique has been successfully employed for large species (bluefin, marlins, sharks, etc.), although most investigators would prefer a more reliable technique if one could be devised. The harpoon method involves the use of flexible nylon or stainless steel leader material to secure the body of the transmitter to a flattened stainless steel harpoon tip (Figure 9). The tip fits loosely into a notch at the end of the applicator pole (harpoon) and the transmitter body is loosely fastened to the harpoon pole with light rubber bands. The transmitter is attached to the fish by impaling the tip in the dorsal musculature with a thrust of the harpoon. The harpoon tip lodges in the muscle or beneath the skin, allowing the harpoon pole to be withdrawn and the transmitter to dangle alongside the body. If the fish has been hooked to bring it to the boat

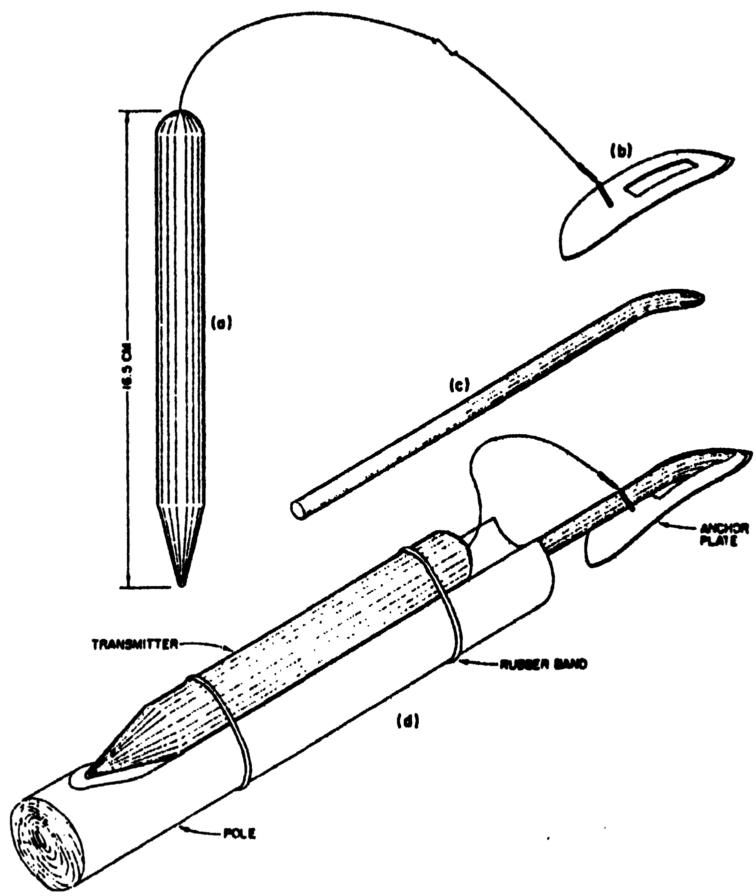

FIGURE 9. Harpoon attachment components (from Yuen, Dizon, and Uchiyama, 1974).

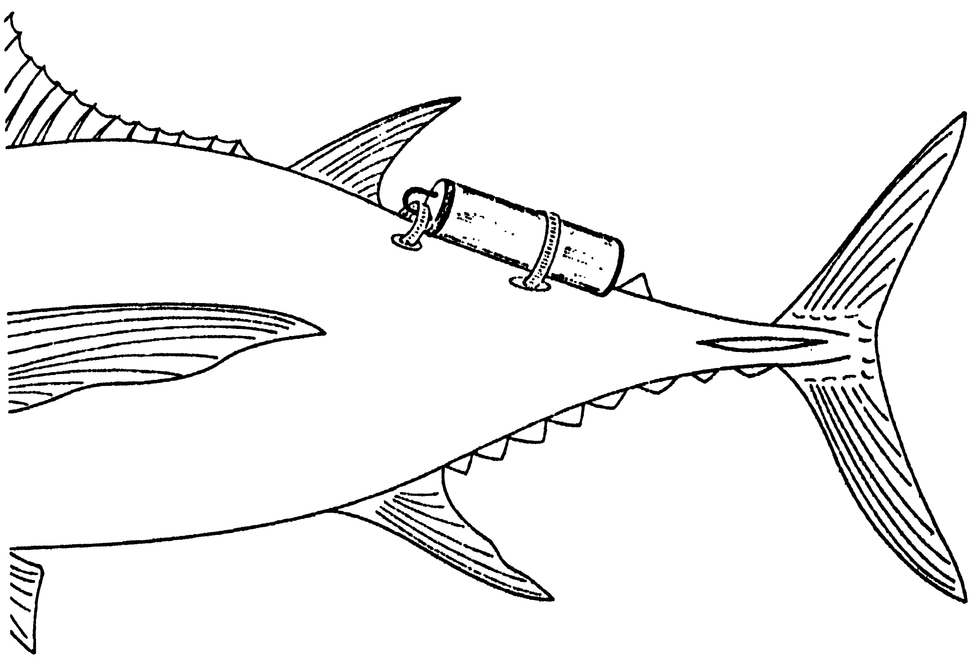

FIGURE 10. Transmitter attachment with two tie-wraps (from Holland et al. in press).

the leader is cut and the fish allowed to swim away (Yuen, Dizon, and Uchiyama, 1974). This method has also been successfully used with free-swimming swordfish which have been harpooned from above as they were swimming or basking at the surface (Carey and Robison, 1981). Although no adverse reactions to the harpoon type of attachment have been reported, the major problem with this method is the uncertainty as to how well the transmitter is attached and how long it will remain in place before pulling out. Nevertheless, tracks of several days duration have been acquired using this technique.

A modification of this method has been employed to acquire muscle temperature data from northern bluefin (Carey and Lawson, 1973). In this case a tubular barbed harpoon tip housed a thermister to monitor the muscle temperature. The tip was rigidly incorporated into the transmitter body. When thrust into the fish, the tip penetrated to a pre-set depth and the transmitter body lay snugly against the skin of the fish.

Stomach insertion involves gently forcing the transmitter down the oesophagus into the stomach of the fish. This is usually performed with a detachable rod which is removed when the transmitter is in place (Yuen, 1970; Carey and Lawson, 1973; Laurs, Yuen, and Johnson, 1977; Dizon, Brill, and Yuen, 1978). This technique seems to work best with large fish such as northern bluefin (Carey and Lawson, 1973). For smaller species, such as skipjack and albacore, problems have occurred due to regurgitation of the transmitter or attenuation of the signal (Laurs, Yuen, and Johnson, 1977; Dizon, Brill, and Yuen, 1978). Of course, when stomach temperature is of particular interest (Carey and Lawson, 1973), there is no alternative to placing the transmitter in the stomach.

The general trend in tuna tracking in recent years has been toward attachment of the transmitter to the external surface of the fish using intramuscular sutures. Two variations have been used. Transmitters have been attached to yellowfin using a single nylon "tie-wrap" suture passed through the muscle and pterygiophores of the anal fin, allowing the transmitter to hang below the fish (Carey and Olson, 1982). The other method is to use two tie-wrap sutures to attach the transmitter to the dorsal surface of the fish. This technique has been successfully employed on albacore (Laurs, Yuen, and Johnson, 1977), and is currently being employed in the study of yellowfin movements around Oahu, Hawaii (Holland _et al._, in press). This technique involves bringing the fish aboard the boat and immobilizing it in a foam-lined cradle. A wet cloth is placed over the fish's eyes to further subdue it while the transmitter is attached. Sharpened hollow needles are used to pass the tie-wrap sutures through the dorsal musculature and pterygiophores associated with the second dorsal fin. One tie-wrap is placed through a loop on the end of the transmitter, and the other is placed around the middle of the transmitter's body to prevent the tag from wobbling from side to side. Both tie-wraps are cinched down and trimmed, and the fish is released (Figure 10). Yellowfin with tags carried in this way have been observed to swim normally in captivity and have yielded consistent data from field tests. Also, a fish with a dorsally attached transmitter was caught 4 weeks after release by a fisherman using a trolling lure (Holland _et al._, in press). These results indicate that intramuscular attachment is a viable method with minimal effects on the fish's behavior. The biggest problem with this technique is the need to bring the fish aboard the boat. This may preclude use of this technique on larger specimens.

3.4 _Hydrophone systems_

Selection of a hydrophone system is largely dictated by the type of pursuit vessel being used. Large vessels which have relatively poor maneuverability have been equipped with rotatable hydrophone heads or multiple hydrophones. These arrangements allow the direction of the transmitter to be ascertained without having to continuously change the

orientation of the vessel (Yuen, Dizon, and Uchiyama, 1974; Laurs, Yuen, and Johnson, 1977). A successful variation of this method involves towing the hydrophone array behind the tracking vessel on a depressor. This technique reduces electrical and mechanical noise generated by the vessel (Carey and Olson, 1982). Smaller, more maneuverable vessels can be equipped with a single directional hydrophone fixed in parallel with the boat's keel. In this case the entire vessel is turned to maximize the strength of the incoming signal and in this way contact is maintained with the fish bearing the tag (Holland et al., in press).

3.5 Data collection and storage

Three types of information are usually collected during tracking experiments. First, the horizontal movements of the fish are monitored. These data are acquired using combinations of Loran-C, radar, depth finder, and visual fixes. The data are usually manually recorded at 15-minute intervals, or more frequently when finer-scale resolution is possible. Such a situation occurs in nearshore locations where precise visual fixes can be supplemented with depth data. In offshore locations horizontal data are usually accurate only to within approximately 200 m, and this usually precludes the need for more frequent or continuous data logging.

Second, depth or physiological data can be continuously recorded on audio cassette tapes from output jacks on the receiver. These tapes can then be analyzed onshore using frequency counters interfaced with computer plotters (Holland et al., in press). Recent receiver models can translate pulse frequency on board the pursuit vessel and give a running real-time record of the fish's depth.

Third, movement and physiological (e.g. muscle temperature) data are greatly enhanced by data concerning the physical and biological environment surrounding the fish carrying the transmitter. The most obvious of these parameters is temperature. Many vertical and horizontal movements of pelagic fish show strong correlations with temperature phenomena (Laurs, Yuen, and Johnson, 1977; Carey and Olson, 1982; Holland et al., in press). The thermal structure of the water column is usually measured by using expendable bathythermographs (XBTs) deployed from the tracking vessel or cooperating vessels. If tracking is conducted from, or in association with, an oceanographic research vessel, oxygen, salinity, and turbidity data can also be acquired. Plankton tows and chlorophyll analyses can provide important data with regard to the biological environment of the area. The advent of sophisticated cathode ray tube and paper fish finders permits previously difficult targets, such as small tunas, to be visualized. Future tracking efforts would greatly benefit from using fish finders that could determine if the tracked fish was travelling in a school.

4. FUTURE PROSPECTS

Purse seines would be the ideal gear to capture most species of tunas for tagging, as they are employed in most areas where tunas are caught and they catch fish ranging in length from about 30 to 200 cm. To date, however, the return rates for fish tagged from purse seiners have been low, due at least partly to the fact that the fish are retained in the net in close quarters for some time prior to tagging (Bayliff, 1973).

In the eastern Pacific yellowfin are often caught in association with porpoises. The fishermen employ a method called "backing down" (Coe and Sousa, 1972) to release the porpoises from the net prior to bringing the tunas aboard. Backing down begins after the fish and porpoises have been encircled, the bottom of the net pursed, and about two-thirds of the net brought aboard the boat. The boat is steered in reverse in a tight clockwise circle, assisted by towing with the skiff. This causes the corkline of the net to assume an eliptical shape with one end at the stern

of the boat and its major axis at a 45-degree angle with that of the boat. The tunas and porpoises tend to segregate themselves to some extent in the net. When porpoises are at the far end of the net additional power is supplied, which submerges the cork line in that area and permits the porpoises to escape. A fisherman in a speedboat is stationed at the far end of the net to depress the corkline when porpoises are escaping, pull it up when tunas are near that end of the net, and release porpoises which are entangled in the net.

Perrin, Evans, and Holts (1979) described a method for tagging porpoises at the far end of the net as they escape during the backing-down process. A floating device, consisting of a shallow central trough for the porpoises and two deeper troughs on either side of the central trough, in which the taggers stand, is used. The porpoises pass through the central trough during backing down, and as they do so they are tagged. Such a system might work for purse seine-caught tunas. The fish would be in better condition that those which had been confined in the net for tagging by the deck method, described earlier. The tags could be applied with a minimum of handling of the fish, and crude measurements of them could be obtained from a scale on the bottom of the trough. This method might produce large numbers of tagged fish, including larger ones which have so far been tagged in only small numbers. The principal problem would probably be inducing the fish to go through the central trough one at a time at rates which are neither too fast nor too slow. Also, employment of this method might be especially difficult in rough weather.

Having now acquired descriptive data for the more important species of tunas using ultrasonic tags, future experiments should be designed around specific hypotheses concerning vertical and horizontal movements in well-defined situations such as thermal boundaries, coastal features, and fish-aggregating devices. The improvement of electronic equipment should allow ultrasonic tracking to become available to a wide range of investigators who previously were unable to work in this field due to prohibitive logistics or cost considerations. In addition to providing increasingly fine-scale movement data, ultrasonic telemetry may soon give direct field measurments of phenomena such as thermoregulation, swimming strategies, and occurrence of feeding bouts.

Hunter et al. (1986) described five types of tags which might be used in the future on tunas. The tagging systems discussed in their report are summarized below. Their list was not exhaustive, but merely included the types which emerged from their discussions. The last three types mentioned would record the geographical position of the fish, which has not been possible with any tags used to date (except tags employing ultrasonic telemetry, which requires that the fish be followed with a boat).

Coded ferromagnetic tags (Jefferts, Bergman, and Fiscus, 1963; Anon., no date) are tiny pieces of wire with binary codes etched or notched in them which are implanted in the flesh of fish as small as about 1/2 g in weight. They remain in the tissue, and their presence is detected by magnetometers in the processing plants or elsewhere. After a tagged fish is detected the etched tags can be removed by dissection and the code read with a microscope, or the notched tags can be read with an x-ray without removing it from the fish. These tags have been used routinely for salmon and herring.

Passive integrated transponder (PIT) tags, which are currently being developed for use with Pacific salmon (Prentice and Park, 1984), can transmit their codes electronically to receivers without harming the fish. The tags have no power source, but respond to radio frequency pulses with coded messages. Their use with tunas will not be not practical in the near future, however, due to their short detection range (about 7.5 cm).

Sonobuoy transponder systems would consist of a number of small floating receivers in fixed positions which would record the presence of fish carrying transmitting tags which swim close to them. No one has attempted to use such a system for any species of fish. For tunas it would probably be most practical in the vicinity of floating fish-aggregating devices.

"Pop-up" tags are tags which would detach themselves from the fish and float to the surface when a specified condition, such as the elapse of a specified period of time, death of the fish, etc., was met. The tags could be detected by aircraft or satellites. Pop-up tags have been developed by Nelson and McKibben (1981) for use with sharks.

Archival position-recording tags have been proposed by Anon. (1983). These tags

> "would contain pressure and temperature sensors, a micro-processor, associated memory and a battery, all sealed in a stainless steel cylinder ... The proposed tag could have a data resolution of one part in 256. Applied to temperature, this means that a total range of -6°C to 32°C would be measured with a resolution of 0.15°C. Depth, measured as pressure, could have three meter resolution over a range of 0 to 768 meters. Accuracy would be comparable to this resolution." (Anon., 1983b).

Data obtained from a tag which measured temperature, depth, and times of sunrise and sunset (and thus day length) could be used to estimate the geographical position of the fish at specified intervals between release and recapture (Hunter *et al.*, 1986). Funding for the development of such a tag is not presently available.

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No: 11208

APPENDIX. Sources of supply for tagging materials.

Vinyl tags

Arthur E. King and Company
Rear 135 King Street
Newtown, Sydney, N. S. W., Australia

Floy Tag and Manufacturing, Inc.
P. O. Box 5357
Seattle, Washington 98105, U. S. A.

Polyethylene tags

Hallprint Pty., Ltd.
27 Jacobsen Crescent
Holden Hill, S. A. 5088, Australia

Tag heads

Riverside Molded Products, Inc.
4213 Hangar Road
Riverside, California 92509, U. S. A.

Vinyl tubing (with or without printing)

Telectronic Laboratories, Inc.
P. O. Box 971
El Monte, California 91731, U. S. A.

Vinyl ink (for marking on pad or cradle covers or hand-numbering tags)

Lee Mark Company
10 635 Marina Vista
Martinez, California 94553, U. S. A.

Steel tubing (for making applicators similar to that shown in Figure 2)

Tubesales
9320 Chesapeake Drive
San Diego, California 92123, U. S. A.

Coded wire tag systems

Northwest Marine Technology
Shaw Island, Washington 98286, U. S. A.

Tetracycline

Anchor Laboratories, Inc.
St. Joseph, Missouri, 64502, U. S. A.

Syringes

Manostat
519 Eighth Avenue
New York, New York, 10018, U. S. A.

Distribution and important biological features of coastal fish resources in Southeast Asia

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